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RANDOM SKEWED JOINTS WITH AND WITHOUT DOWELS

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16. Abstract

The objective of this study was to compare the performance of a nonreinforced concrete pavement with random spaced, skewed contraction joints using dowels bars versus one without dowel bars. A one mile test section with dowel bars and a one mile control section without dowel bars were constructed in 1984. The new pavement consisted of a 11" nonreinforced recycled concrete pavement over a 12" crushed aggregate base course. In the test section, epoxy coated dowel bars were placed on dowel basket assemblies, positioned at the contraction joints. The contraction joints were spaced in a repeating "random" pattern of 12, 13, 19, & 18 feet, skewed right hand forward across both lanes, and sealed with preformed elastomeric compression joint seals.

The pavements were evaluated over a twelve-year period based on construction (efficiencies/deficiencies), pavement performance (visual inspections, ride, load transfer efficiency, faulting, dowel bar corrosion), and costs. While the doweled pavement performed well throughout the study period, the non-doweled pavement experienced progressive deterioration, primarily in the form of faulting. In 1994, after ten years of service, the non-doweled pavement was diamond ground due to poor performance. A 1996 field survey showed the twelve-year old doweled pavement to be in good condition, while the ground non-doweled pavement was beginning to show signs of reoccurring faulting. The study conclusions follow:

1) The doweled pavement continues to perform better than the non-doweled pavement.
2) The life of the doweled pavement is estimated to last approximately 2.5 times longer than the non-doweled pavement prior to any maintenance or rehabilitation.
3) The epoxy coated dowel bars in the test section remained intact (i.e. no corrosion).
4) The use of dowel bars increases initial concrete pavement cost by approximately 7.8 percent.
5) Over a 25-year service life, a non-doweled pavement would cost approximately 13.1 percent more than a doweled pavement.
6) The use of dowel bars in concrete pavements currently saves WisDOT approximately $6,000,000 per year.
7) The employment of dowel bars is a cost effective method of extending the service lives of concrete pavements while enhancing the pavement performance and reducing user inconvenience.

Today, WisDOT's standard design procedures include the use of epoxy coated dowel bars for all new concrete pavements. The conclusions of this study strongly support this practice. Based on excellent performance of doweled pavements statewide and the results of this study, WisDOT will continue to employ dowel bars in all new concrete pavements.

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FEDERAL EXPERIMENTAL PROJECT # WI 85-01

FINAL REPORT WI/FEP-07-96
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BY

DEBRA L. BISCHOFF
RESEARCH PROJECT ENGINEER

WISCONSIN DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION INFRASTRUCTURE DEVELOPMENT
BUREAU OF HIGHWAY CONSTRUCTION
PAVEMENT RESEARCH UNIT
3502 KINSMAN BLVD., MADISON, WI 53704

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INTRODUCTION

The objective of this study was to compare the performance of a nonreinforced concrete pavement with random spaced, skewed contraction joints using dowels bars versus one without dowel bars.

PROJECT SITE

This research project was comprised of one test section and one control section which were incorporated into a larger scaled highway improvement project located just west of Menomonie, Wisconsin, in Dunn County (Figure 2, page 9). This project's scope involved the reconstruction, in 1984, of 21.8 km (13.6 mi) of concrete pavement in both eastbound lanes of I-94.

The control section began approximately 7.2 km (4.5 mi) west of USH 12 and continued east for 1.6 km (1 mi). The new pavement consisted of a 275 mm (11") nonreinforced recycled concrete pavement over a 300 mm (12") crushed aggregate base course. The contraction joints were spaced in a repeating "random" pattern of 3.7, 4.0, 5.8, and 5.5 meters (12, 13, 19, & 18 feet) and skewed right hand forward across both lanes. The contraction joints were sealed with preformed elastomeric compression joint seals. No dowel bars were used in this section. The remainder of the project, with the exception of the test section, was constructed in the same manner.

The test section, which had similar subgrade characteristics, adjoined the east end of the control section and was also 1.6 km (1 mi) in length. The new pavement was also comprised of a 275 mm (11") recycled concrete pavement over a 300 mm (12") crushed aggregate base course. Epoxy coated dowel bars were placed on dowel basket assemblies which were positioned at the random spaced, skewed contraction joints to effect load transfer. The dowel bars were 35 mm (1.38") in diameter, 450 mm (18" long), and were placed 140 mm (5.5") below the pavement surface. The first dowel bar was positioned 150 mm (6") from the pavement edge. The remainder of the dowel bars were spaced 300 mm (12") apart across the joint. Approximately 8,160 dowel bars were installed in the test section. The contraction joints in this section were also sealed with preformed elastomeric compression joint seals.

OBJECTIVES

The objectives of this study were to evaluate the pavement performance of both the test section and the control section over a twelve-year period with respect to:

- Construction Phase
  - Efficiencies/deficiencies
- Performance
  - Visual Inspections
  - Ride
  - Load Transfer Efficiency
  - Faulting
  - Dowel Bar Corrosion
- Costs

CONSTRUCTION PHASE

Both sections were constructed in conformance with plans, Standard Specifications, and Special Provisions of the Wisconsin Department of Transportation (WisDOT). There were no significant problems constructing either one, although the doweled pavement required more manual effort in placing the dowels and in locating the sawed joints.

PERFORMANCE

<u>VISUAL INSPECTIONS</u>

Visual inspections of the pavement were conducted throughout the study period. While the doweled pavement performed well throughout the study period, the non-doweled pavement experienced progressive deterioration, primarily in the form of faulting. Due to the poor performance, in 1994, after ten years of service, the entire project length of non-doweled pavement, including the control section, was diamond ground.

A recent field survey showed the twelve year old doweled pavement to be in good condition, while the ground non-doweled pavement is beginning to show signs of reoccurring faulting. These signs are very minute, however, and the ground pavement has been estimated to last a total of eight to ten years before requiring additional maintenance. A second grinding of the pavement, if needed, would probably last less than ten years before requiring additional maintenance. The doweled pavement, on the other hand, is expected to last a total of 25 years before requiring any maintenance. Thus, it has been estimated that the non-doweled pavement will require to be ground twice to attain a service life equivalent to that of the doweled pavement.

Various tests were performed on both the test section and the control section throughout the study period, the results of which are summarized below. The non-doweled control section consistently showed inferior results to the doweled test section.

RIDE

The International Roughness Index (IRI), previously the Pavement Serviceability Index (PSI), is a ride quality measurement based on pavement roughness. Testing was conducted annually, with a road profiler, over the entire project length. The initial IRI value over most of the project length, including the test section and the control section, was 1.4 m/km (5.0 PSI), which reflects a good, quality ride.

The doweled pavement provided a quality ride throughout the study period and continues to do so. The non-doweled pavement, on the other hand, provided a ride which progressively deteriorated over the study period. In 1994, just prior to being diamond ground, the average IRI value of the non-doweled pavement, over the entire project length, was approximately 2.6 m/km (2.5 PSI), while that of the doweled pavement was approximately 1.6 m/km (4.5 PSI).

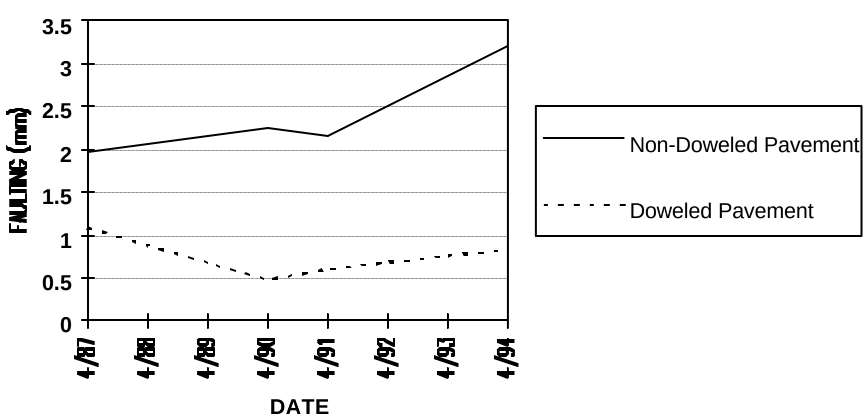
LOAD TRANSFER EFFICIENCY

The load transfer values, obtained by using a Falling Weight Deflectometer (FWD), represents the percent of load which is transferred at pavement joints between abutting slabs. The final values were obtained in the summer of 1994, at ten different joint locations in both the test section and the control section. The average load transfer was 75% for the non-doweled pavement and 84% for the doweled pavement. Although winter month values were not obtained for this study, previous studies have indicated that the load transfer efficiency on non-doweled pavements will be very low in cool months, while doweled pavements will retain a high load transfer efficiency.

FAULTING

Faulting is the vertical displacement of abutting slabs at joints or cracks. Prior to grinding the non-doweled pavement in 1994, the faulting was measured periodically at ten different joint locations in both the test section and the control section. The average faulting values of the ten year old pavement were determined and are shown below in Figure 1.

FIGURE 1: AVERAGE FAULTING MEASUREMENTS (PRIOR TO GRINDING)



The faulting values of the doweled pavement ranged from 0.64 mm (0.03”) to 1.1 mm (0.05”), with an average faulting value of 0.83 mm (0.03”), and were consistently lower than those of the non-doweled pavement which ranged from 1.7 mm (0.07”) to 4.6 mm (0.18”), with an average faulting value of 3.2 mm (0.13”).

DOWEL BAR CORROSION

In 1989, after five years of service, partial depth core samples were taken in the doweled test section at randomly selected joints. A total of eight samples were taken, none of which showed any corrosion present on the dowel bars. The epoxy coating of the dowel bars, at the coring locations, remained intact.

COSTS

The original cost figures are not available; however, it can be assumed that the initial cost of the non-doweled pavement was less than the initial cost of the doweled pavement, obviously due to the absence of dowels. Using current prices, the average costs of pavements and dowels are as follows:

275 mm (11”) Doweled PCC = $\$18.19/m^2$ ($\$15.21/yd^2$)

Dowels = $\$1.31/m^2$ ($\$1.10/yd^2$)

275 mm (11”) Non-Doweled PCC = $\$16.88/m^2$ ($\$14.11/yd^2$)

From these values, it was determined that the use of dowel bar assemblies currently increases the initial cost of 275 mm (11”) concrete pavements approximately 7.8 percent.

To compare the total cost of a doweled pavement to the total cost of a non-doweled pavement, over a 25-year service life, the total Present Worth of the pavements must first be determined. Since the cost of a doweled pavement, over a 25-year service life, involves only the initial cost, the total Present Worth is equal to the initial cost.

$$\text{Total Present Worth of a Doweled PCC} = \$18.19/m^2\ (\$15.21/yd^2)$$

The total Present Worth of a non-doweled pavement, on the other hand, over a 25-year service life, involves the initial cost of the pavement plus the cost of two grindings. The current average price of grinding is:

$$\text{Grinding} = \$3.73/m^2\ (\$3.12/yd^2)$$

Since grinding costs are accrued in the future, after pavement deterioration has occurred, the costs must be converted to Present Worth costs as follows:

$$\text{Present Worth of First Grinding (in 10 years)} = F(1+i)^{-n};$$

where F = future worth,

i = discount rate of 5%, and

n = number of years;

$$\text{Present Worth of First Grinding} = \$3.73(1+0.05)^{-10} = \$2.29/m^2\ (\$1.92/yd^2)$$

Therefore, the cost of a first grinding, from an economical standpoint, is approximately 13.6 percent of the original non-doweled pavement cost. Furthermore, assuming that a non-doweled pavement will require grinding twice to attain a service life equivalent to that of a doweled pavement, the following calculation can be performed:

$$\text{Present Worth of Second Grinding (in 20 years)} = \$3.73(1+0.05)^{-20} = \$1.41/m^2\ (\$1.18/yd^2)$$

Therefore, the cost of a second grinding, from an economical standpoint, is approximately 8.4 percent of the original non-doweled pavement cost. Hence:

$$\text{Total Present Worth of a Non-Doweled Pavement} = \$16.88 + \$2.29 + \$1.41$$

$$= \$20.58/m^2\ (\$17.21/yd^2)$$

Comparing the total Present Worth of a Non-Doweled Pavement to the total Present Worth of a Doweled Pavement yields:

$$(\$20.58-\$18.19)/\$18.19 = 13.1\%$$

Hence, over a 25-year service life, a 275 mm (11”) non-doweled pavement would cost approximately 13.1 percent more than a 275 mm (11”) doweled pavement. Even if the non-doweled pavement were only ground once during the pavement life, it would still cost about 5.4 percent more than the doweled pavement.

Furthermore, the grinding of pavements would require additional expenses such as traffic control and pavement marking which, for reasons of simplicity, were not included in this analysis. These costs would clearly increase the total cost of non-doweled pavements, thereby making doweled pavements even more cost-effective.

Based on the above economic analysis and using Fiscal Year 1996 quantities for new and rehabilitated PCC pavements, it can be concluded that using doweled pavements currently saves WisDOT approximately \$6,000,000 per year. This analysis, once again, excludes the additional costs to the Department of traffic control and pavement marking generated by pavement grinding, which would clearly result in even greater savings.

CONCLUSIONS

1. The doweled pavement continues to perform better than the non-doweled pavement.
2. The life of the doweled pavement is estimated to last approximately 2.5 times longer than the non-doweled pavement prior to any maintenance or rehabilitation.
3. The epoxy coated dowel bars in the test section remained intact (i.e. no corrosion).

4. The use of dowel bars increases initial concrete pavement cost by approximately 7.8 percent.
5. Over a 25-year service life, a non-doweled pavement would cost approximately 13.1 percent more than a doweled pavement.
6. The use of dowel bars in concrete pavements currently saves WisDOT approximately $6,000,000 per year.
7. The employment of dowel bars is a cost effective method of extending the service lives of concrete pavements, while enhancing the pavement performance and reducing user inconvenience.

RECOMMENDATIONS

WisDOT has, over the years, become aware of the enhanced performance of concrete pavements due to the employment of dowel bars. Today, WisDOT's standard design procedures include the use of epoxy coated dowel bars for all new concrete pavements. The conclusions of this study strongly support this practice. Based on the excellent performance of doweled pavements statewide and the results of this study, it is recommended the WisDOT continue to employ dowel bars in all new concrete pavements.

FIGURE 2. RANDOM SKEWED JOINTS WITH AND WITHOUT DOWELS I-94, DUNN COUNTY